NASA/TM—2002-211371 AIAA–2002–0762

Physics of Colloids in Space: Flight Hardware Operations on ISS

Michael P. Doherty
Glenn Research Center, Cleveland, Ohio

Arthur E. Bailey
Scitech Instruments, Inc., North Vancouver, British Columbia, Canada

Amy L. Jankovsky
Glenn Research Center, Cleveland, Ohio

Tibor Lorik
ZIN Technologies, Inc., Brook Park, Ohio

February 2002

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized data bases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at *http://www.sti.nasa.gov*
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at 301–621–0134
- Telephone the NASA Access Help Desk at 301–621–0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076

NASA/TM—2002-211371

AIAA–2002–0762

Physics of Colloids in Space: Flight Hardware Operations on ISS

Michael P. Doherty
Glenn Research Center, Cleveland, Ohio

Arthur E. Bailey
Scitech Instruments, Inc., North Vancouver, British Columbia, Canada

Amy L. Jankovsky
Glenn Research Center, Cleveland, Ohio

Tibor Lorik
ZIN Technologies, Inc., Brook Park, Ohio

Prepared for the
40th Aerospace Sciences Meeting and Exhibit
sponsored by the American Institute of Aeronautics and Astronautics
Reno, Nevada, January 14–17, 2002

National Aeronautics and
Space Administration

Glenn Research Center

February 2002

Acknowledgments

The authors wish to acknowledge the members of the PCS development, operations, and science teams, including, but not limited to: John Bowen, Rebecca Christianson, Kevin Dendorfer, Mike Dobbs, Jeff Eggers, Urs Gasser, Carol Kurta, Suliana Manley, Vikram Prasad, Bill Shiley, Subra Sankaran, and Rafat Ansari. The dedicated efforts of each team member toward development, qualification, turnover, mission preparations, launch, and operations has led the project toward meeting its technical, quality, and schedular goals. In addition, the dedication of the PCS operators and scientists to working the erratic hours that are characteristic of this ISS payload does not go unnoticed. All team members have had a part in making PCS the success that it is.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at http://gltrs.grc.nasa.gov/GLTRS

PHYSICS OF COLLOIDS IN SPACE: FLIGHT HARDWARE OPERATIONS ON ISS

Michael P. Doherty
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Arthur E. Bailey
Scitech Instruments, Inc.
North Vancouver, British Columbia, Canada

Amy L. Jankovsky
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Tibor Lorik
ZIN Technologies, Inc.
Brook Park, Ohio 44142

ABSTRACT

The Physics of Colloids in Space (PCS) experiment was launched on Space Shuttle STS-100 in April 2001 and integrated into EXpedite the PRocess of Experiments to Space Station Rack 2 on the International Space Station (ISS). This microgravity fluid physics investigation is being conducted in the ISS U.S. Lab 'Destiny' Module over a period of approximately thirteen months during the ISS assembly period from flight 6A through flight 9A. PCS is gathering data on the basic physical properties of simple colloidal suspensions by studying the structures that form. A colloid is a micron or sub-micron particle, be it solid, liquid, or gas. A colloidal suspension consists of these fine particles suspended in another medium. Common colloidal suspensions include paints, milk, salad dressings, cosmetics, and aerosols. Though these products are routinely produced and used, we still have much to learn about their behavior as well as the underlying properties of colloids in general. The long-term goal of the PCS investigation is to learn how to steer the growth of colloidal structures to create new materials. This experiment is the first part of a two-stage investigation conceived by Professor David Weitz of Harvard University (the Principal Investigator) along with Professor Peter Pusey of the University of Edinburgh (the Co-Investigator).

This paper describes the flight hardware, experiment operations, and initial science findings of the first fluid physics payload to be conducted on ISS: The Physics of Colloids in Space.

INTRODUCTION

PCS is an EXPRESS Rack-based microgravity science experiment currently being performed on the International Space Station until August 2002. (EXPRESS stands for EXpedite the PRocessing of Experiments to Space Station, and the EXPRESS Rack is one of the types of experiment accommodation facilities available on the ISS.) PCS is currently gathering data on the basic physical properties of colloids by concurrently studying three different types of colloidal suspensions with the objective of understanding how colloidal structures grow, the rates at which they grow, and the structures that they form. This information provides insight into the basic nature of liquid-to-solid phase transitions, how colloidal constituent properties affect the properties of the bulk colloidal suspension, and the unique optical properties of nano-engineered binary colloidal alloys. Microgravity is required to eliminate the effects of sedimentation, which on Earth prevents the structures from growing because of the extended periods of time required for them to nucleate and grow. The potential payoffs of PCS

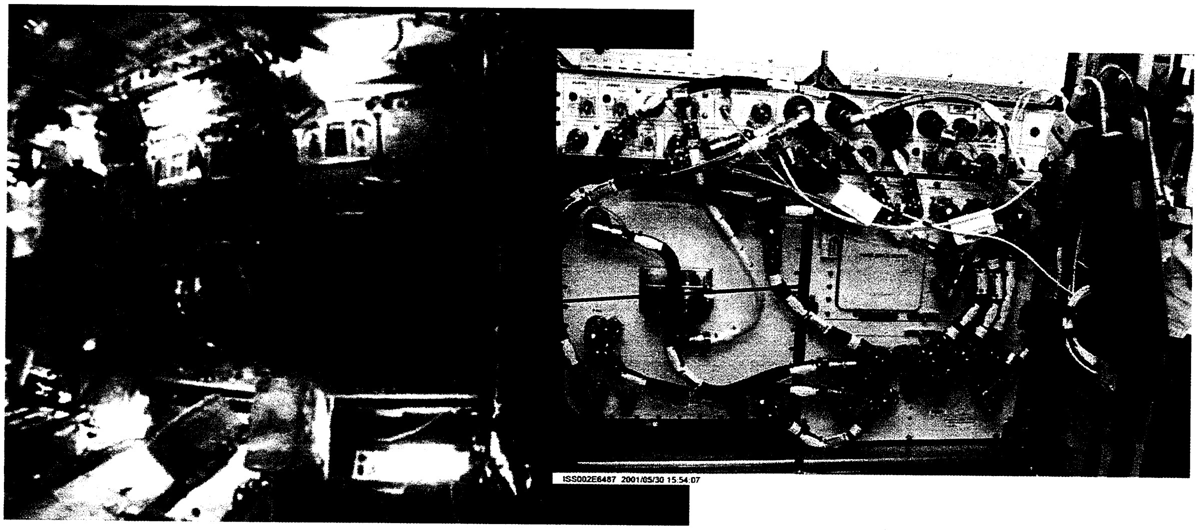


Figure 1. PCS on ISS

include improvements in the properties of paints, ceramics, and food and drug delivery products, decreased product development time and more efficient production of end products having colloidal suspensions as precursors, and possibly the development of an entirely new class of materials which can passively affect the properties of light passing through them. Such materials may find uses as optical switches and lasers for advanced communications and displays. Industries using semiconductors, electro-optics, ceramics and composites are among those that may benefit from colloid research.

PCS is being remotely operated from the NASA Glenn Research Center's (GRC) Telescience Support Center in Cleveland, Ohio and at an established remote site at Harvard University in Cambridge, Massachusetts. The two locations permit daily remote tele-operation of this microgravity experiment. A significant amount of science data and results are being downlinked in near real time, enabling interim results to be obtained.

This paper will review the PCS hardware on ISS, including its diagnostics and samples, give a detailed explanation of the near-daily operations of PCS from GRC and Harvard, and provide a look at the PCS science findings to date.

HARDWARE, DIAGNOSTICS, AND SAMPLES

The PCS experiment hardware is comprised of an Avionics unit and a Test section unit, each approximately 47×50×56 cm in size. The Test Section and Avionics Section are accommodated side by side in ISS EXPRESS Rack 2, occupying four Middeck Locker Equivalents of rack volume (Figure 1). The PCS hardware uses the EXPRESS Rack utilities of power, air-cooling, water-cooling, and communication for commanding and data telemetry. The PCS Avionics Section provides power distribution, command and data communication, data acquisition and processing, and data storage on 18 GB removable hard drives. The PCS Test Section contains eight colloid samples and all the diagnostic instrumentation. A schematic of the PCS science diagnostics is shown (Figure 2). These diagnostics are mostly light scattering instrumentation, which was substantially developed under a previous flight experiment, the Physics of Hard Spheres Experiment (PHaSE).[1,2] Dynamic and Static (D&S) Light Scattering (aka fiber scattering) is provided via a 532 nanometer Nd-YAG laser and fiber-coupled single photon counting detectors. Two detection fibers simultaneously collect light at scattering angles from 11° to 169° and the complementary angle. Bragg scattering is measured over the range from 10° to 60° by

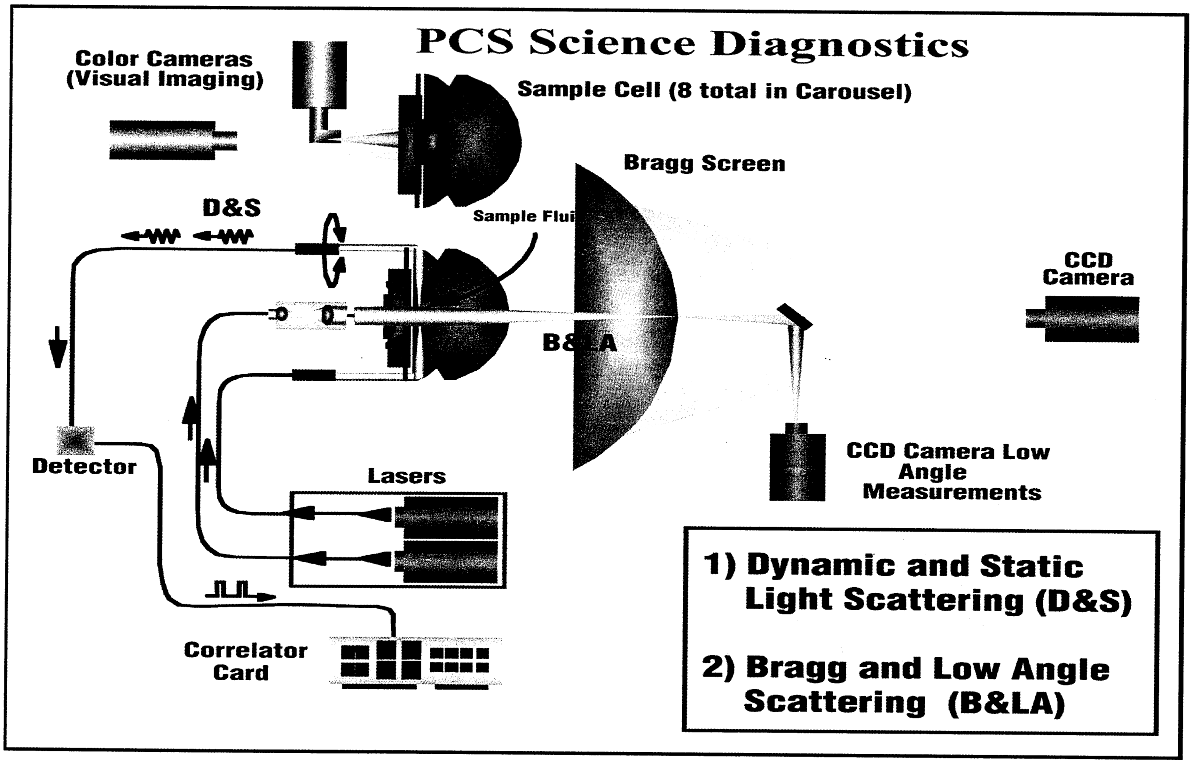


Figure 2. Schematic of the PCS Science Diagnostics

imaging the scattering from a second Nd-YAG laser on an optical screen with a digital camera. Additional optics and a second digital camera capture the laser light scattered at low angles of 0.3° to 6.0°. Via the electronics and data processing provided by the Avionics Section, both static and dynamic light scattering data is obtained from the low scattering angle optics and camera. Static light scattering refers to the measurement of the average angular distribution of the scattered light. This distribution is a measure of the Fourier transform of the mass-to-mass correlations in the sample, meaning that this type of measurement provides information about the sizes or positions of the colloids or structures formed and how they are arranged on length scales up to approximately 5 microns. Dynamic light scattering is a technique that measures the spectral width or time dependence of the scattered light, resulting from the motions of particles or structures. Two color cameras (1x and 10x magnification) provide real-space images on macroscopic length scales (to complement the Fourier-space light scattering on microscopic length scales). A detailed description of the PCS hardware has been previously given by Ansari et al.,[3] while a detailed description of the PCS experiment objectives has been provided by Doherty et al.[4] A detailed description of the hardware operations and command capability is provided by Bowen in the PCS Operations Manual.[5]

The experiment focuses on the behavior of three different classes of colloid mixtures of tiny manmade particles of either polymethyl methacrylate (PMMA), silica or polystyrene. The samples being studied include binary colloidal crystal alloys, colloid-polymer mixtures, and fractal gels. Binary colloidal crystal alloys are dispersions of two different size particles in an index-matching fluid. Colloid-polymer mixtures are solutions of mono-disperse particles mixed with a mono-disperse polymer in an index-matching fluid, where the phase behavior—solid, liquid, and gas—is controlled by the concentration of the colloid, the concentration of the polymer, and the relative size of the colloid and the polymer. Fractal gels form when charged colloids have their electrostatic repulsions screened out by the addition of a salt solution on-orbit, allowing aggregation. In all, PCS contains a total of eight approximately 3 milliliter volume colloid samples, each contained by a glass cell stationed within a remotely controlled carousel inside the PCS Test Section.

Initiation of an investigation on each colloid sample occurs when it is homogenized (that is, stirred up via the oscillation of the sample cell within its bearings) to evenly distribute its suspended particles and then allowed to sit for days, weeks, or months on orbit. During this interval, particles in the samples will organize themselves—that is, self-assemble—into crystal-like or gel-like arrangements. Meanwhile, the laser light scattering and visual imaging diagnostics are utilized to gather structural information about the samples during this crystallization or gelation process. All samples, except the two fractal gels, can be rehomogenized (reinitiated) to repeat a measurement at another sampling rate or to utilize a different measurement technique to examine their behavior in a complementary way. The fractal gels can only be run once. For all samples, measurements are taken every few seconds immediately after homogenization and then with less frequency (typically for a few hours each week) over a several-month period, with on-going experimentation planned to take place for over 13 months. The measurements readily provide the Principal Investigator with information on the growth, the size, and the type of structures formed.

EXPERIMENT OPERATIONS

Operations of PCS are conducted remotely from the ground. A payload operations team at NASA Glenn Research Center's Telescience Support Center (TSC) and a science team at Harvard University monitor and command PCS (Figure 3). All science runs are coordinated with NASA Marshall Space Flight Center's Payload Operations and Integration Center (POIC) for command opportunity and ISS resources. During payload commanding, the PCS operator/commander is in continual contact with the POIC via headset and voiceloop. Minimal crew time is required for PCS operations beyond hardware setup and activation, deactivation and removal, and transfer to and from the Space Shuttle. The crew performs data hard drive changeouts as well as unplanned diagnostic or shutdown procedures as required.

Figure 3. The Glenn Research Center's Telescience Support Center

On orbit, the PCS experiment hardware is powered on for discrete periods of time (12, 24, or 48 hours) on average three to four times per week. The POIC turns on the power to PCS. Then the PCS operator sends a startup command and uplinks the day's unique script to execute the science team's planned experiment run. Harvard University determines ahead of time which diagnostics to run, which parameters to run the diagnostic under, which sample(s) to examine, and what sequence to use, while the GRC payload operations team is responsible for the scripting and execution of the commands. Additionally, the payload operations team ensures downlink of the data files once collected, and distribution of these data in near real time for science team evaluation, helping to prepare for the next series of runs. An example of a 24 hour run might be: perform low angle static scattering and low angle dynamic scattering on one sample (15 minutes + 10.5 hours), perform Bragg scattering, low angle static scattering, photo imaging, and fiber static scattering on a second sample (15 + 15 + 15 minutes + 1 hour), perform Bragg scattering, low angle static scattering, and photo imaging on a third sample (15 + 15 + 15 minutes), and then conclude by repeating the two low angle measurements on the first sample.

The PCS physical mission operations architecture is diagrammed in Figure 4. The heart of the architecture are the four Telescience Resource Kit (TReK) workstations which enable payload commanding and monitoring as well as initial display of science data. For payload commanding, the PCS commander logs into a POIC workstation and runs an application through an X-Window session. Data arrives at the TSC as well as the Harvard remote site via land lines from the MSFC POIC. The telemetry data (consisting of data items from the analog, discrete, motor, downlink, and software flight modules), instantaneously displayed and updated at one second intervals, coupled with a running log of the PCS instrument command status (i.e., 'command received,' 'command

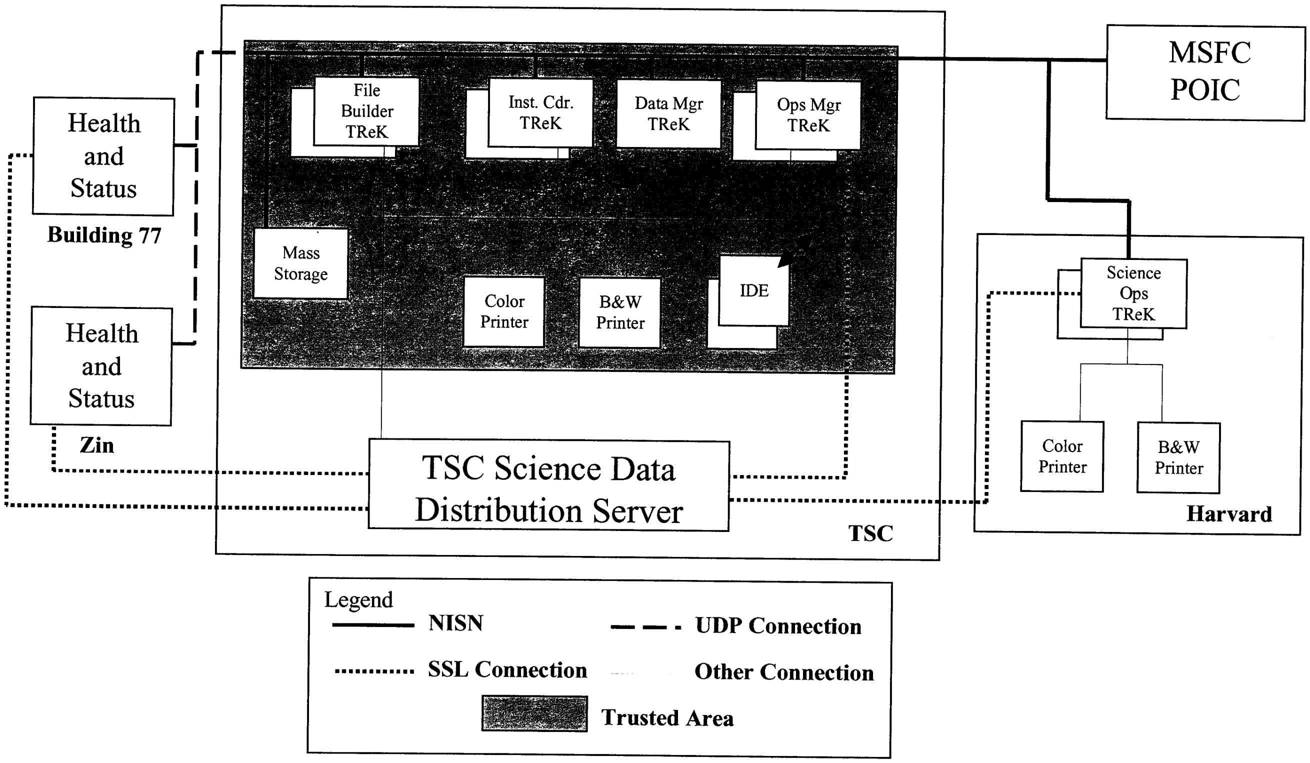


Figure 4. PCS Mission Operations Architecture

complete') provides both the payload operations team and science team with a continual status of the flight instrument. The science data is automatically downlinked at the end of each diagnostic. A File Builder application on the ground receives the science file packets and re-assembles them into a contiguous file. An Image Display application converts raw image files into an on-screen picture. A manually driven data formatting and archiving process is then executed to store the science data on the GRC Science Data Distribution Server, where it subsequently can be accessed by the PI and science team via secure socket layer world wide web protocol. Thus, although there are a few manual steps involved, science results are made available to Harvard quickly enough to assess the quality of the diagnostic run, often within a few hours of its completion.

During operations, the ISS will enter and leave areas of satellite coverage. Regardless of satellite coverage, the flight instrument will continue to downlink its data. An ISS data recorder facility enables data transmitted during loss of signal to be received during a subsequent acquisition of signal. The PCS operators also may request any data file on the flight hard drives to be retransmitted if there is a loss or corruption of the file during transmission.

Additional resources at the hands of the PCS operations and science team are an electronic console log, an Integrated Desktop Environment (IDE) workstation, and a mass storage device. The console log, updated continually by the operations team to provide a brief synopsis of significant events, is accessible via the internet to provide experiment run progress to the science team as well as to future operations shifts. The IDE machine also provides email to enable the detailed communications among the operators, scientists, and POIC Cadre. Mass storage provides a tape backup of all raw data.

SCIENCE RESULTS

PCS was activated on May 31, 2001, completed its checkout operations on June 22, 2001, and survey of all samples by mid-August. Since then, all six re-homogenizable samples have been investigated in good detail. For the binary colloidal crystal

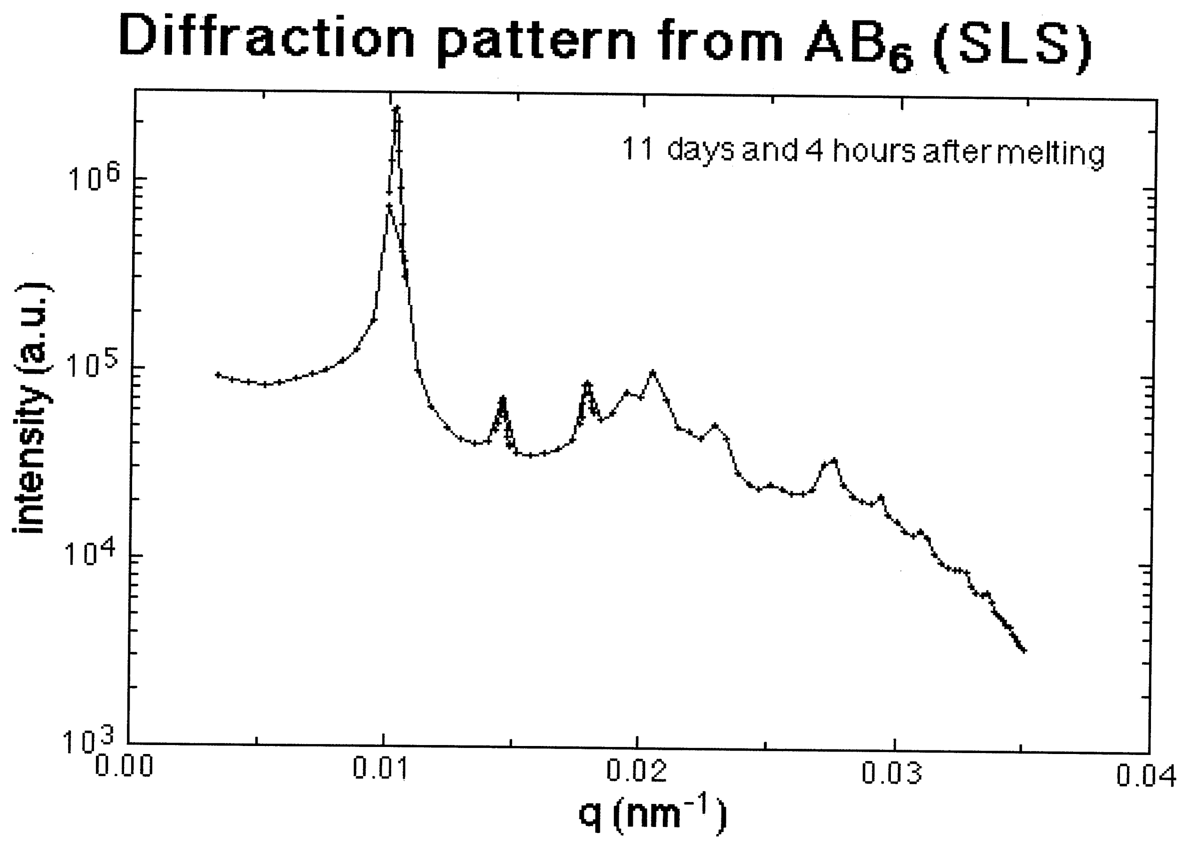
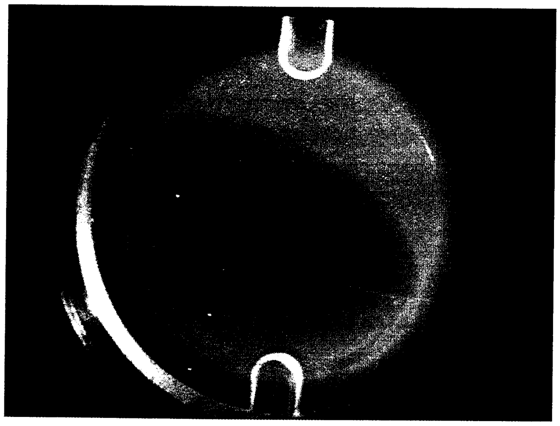


Figure 5. AB6 Binary Colloidal Crystal Alloy Fiber Static Scattering

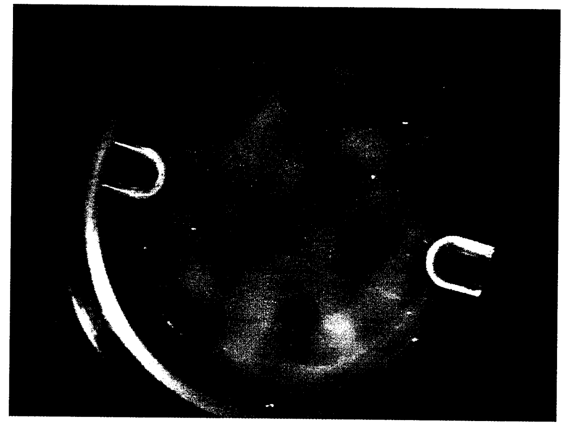
alloys, crystal nucleation and growth and the resultant structures have been studied. The crystalline structures agree with the PI's expectations, while the growth and coarsening of the crystals (evolution of the structure) has proven to be somewhat different than expected. Figure 5 is a diffraction pattern of one of the binary colloidal crystal samples taken 11 days and 4 hours after sample homogenization (melting) using the fiber static scattering diagnostic. Due to the large accessible q-range (corresponding to the 11° to 169° angular range for fiber scattering) many Bragg peaks are observable, enabling detailed structure analysis. Growth and coarsening of crystals is measured from the time evolution of the height and width of these peaks.

The behavior of the colloidal-polymer samples is quite complex and has resulted in several very interesting observations. In particular, immediately after mixing the two-phase-like Colloid-Polymer Critical Point sample begins to phase separate or de-mix into two phases—one that resembles a gas and one that resembles a liquid, except that the particles are colloids and not atoms. As shown in Figure 6, the colloid poor black regions (colloidal gas) grow bigger, and the colloid rich white regions (colloidal liquid) become whiter, as the domains further coarsen. Finally, complete phase separation is achieved, that is, just one region of each colloid-rich (white) and colloid-poor (black) phase. In addition, the science and operations teams designed and executed a diagnostic sequence which captured and condensed the first 16 hours of this sample's de-mixing into a 7 second long time lapse movie. None of this behavior can be observed in the sample on Earth because sedimentation would cause the colloids to fall to the bottom of the cell faster than the de-mixing process could occur.

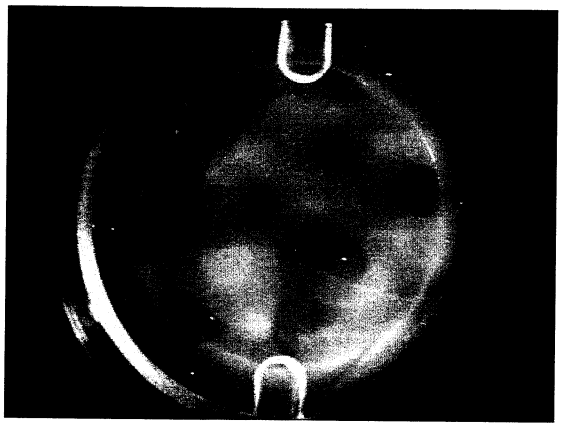
The study of aging of another colloid-polymer sample, the Colloid-Polymer Gel, reveals that once the gel network spans the sample cell and the fluid no longer flows (i.e., gelation is complete), aging of the gel occurs. Aging refers to the evolution of the gel's structure and to its internal motions during that time. This gelation and aging scenario is much



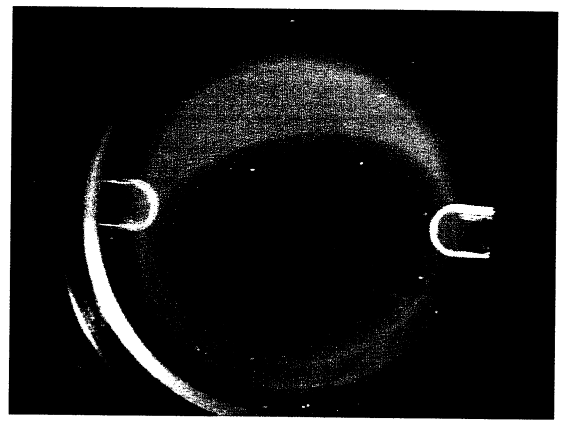
1. Premixed



2. 3 hrs 50 min after mix



3. 13 hrs 24 min after mix



4. 35 Days, 2 hrs, 54 min after mix

Figure 6. Evolution of Colloid-Polymer Critical Point Sample

like the hardening of jello here on Earth—the gel structure forms rapidly, but the gel network continues to evolve (become stiffer). These aspects of the colloid-polymer samples are very interesting because fundamental mechanisms of the formation and evolution of phases, crystals, and networks of suspensions driven by the concentration of the polymer additives are being observed to a greater degree than has been previously possible.

Overall, experiments performed to date by PCS have proceeded well with the instrumentation exceeding the PI team's expectations.

CONCLUSION

Operations of PCS on ISS are planned through August 2002. Experiments remaining to be executed are the fractal gel investigations and deeper studies of the colloid-polymers and the binary colloidal crystal alloys. The primary goals of the fractal gel investigation are the study of gel structures and, more importantly, aging of gels which cannot be studied in the presence of gravity. The first fractal is scheduled for initiation in January 2002, followed by the second four weeks later. For the other samples, the science team plans to re-homogenize and one-by-one examine sample behavior and collect diagnostic data not yet seen or not yet seen to the desired detail. Examples of such behavior are: observe and measure internal crystal dynamics for the binary colloidal crystal alloy samples, examine gel viscoelasticity and study gel aging for the Colloid-Polymer Gel sample, and measure interfacial fluctuations for the Colloid-Polymer Critical Point sample.

NASA GRC is now planning to de-orbit only the PCS Test Section (and several of the removable hard drives that have been filled) on ISS Flight 9A, STS-112, Space Shuttle Atlantis. The Avionics Section and cable harnesses will remain on orbit. Upon de-orbit, the Test Section will be outfitted with eight new samples from a second Principal Investigator. The Test Section will then be relaunched approximately 9 months later, reintegrated into the EXPRESS Rack alongside the Avionics Section, recabled and re-activated, with operations resuming for an additional 9 months. This will enable essentially twice the science to be accomplished with the same flight hardware, while yielding a launch mass savings of about 90 kg (the mass of what is being left on orbit).

PCS is fundamental science, but it has applications to everyday life. Potential payoffs are improvements in the properties of drug delivery products (e.g., encapsulation of drugs) food (i.e., shelf life) cosmetics (optical properties) and paints (ease of application, sheen, weatherability). In addition, potential payoffs of PCS include advances in colloid engineering, expected to yield photonic band gap crystals, which affect the properties of light passing through them. Eli Yablonovitch of the University of California at Los Angeles states, "Many researchers believe that integrated circuits that combine conventional electronics and photonics stand ready to extend the integrated-circuit revolution into the domain of high-bandwidth optical signals."[6] This understanding could fuel technological leaps in our telecommunications networks technologies.

REFERENCES

1. C.T. Lant, A.E. Smart, D.S. Cannell, W.V. Meyer, and M.P. Doherty, "Physics of hard spheres experiment - a general purpose light scattering instrument," Appl. Opt. **36**, 7501–7507 (1997).

2. M.P. Doherty, C.T. Lant, J.S. Ling, "The Physics of Hard Spheres Experiment on MSL-1: Required Measurements and Instrument Performance," AIAA–98–0462 (1998).

3. R.R. Ansari, E.A. Hovenac, S. Sankaran, J.M. Koudelka, D.A. Weitz, L. Cipelletti, and P.N. Segre, "Physics of Colloids in Space Experiment," Space Technology and Applications International Forum, STAIF-99 (1999).

4. M.P. Doherty, J.M. Koudelka, S.M. Motil, S.M. Saavedra, "Light Scattering for Complex Fluids Research on ISS: Investigator Dreams and Anticipated Hardware Development," AIAA–99–0964 (1999).

5. J. Bowen, "PCS Operations Manual," PCS-DOC-050, unpublished (2001).

6. E. Yablonovitch, "Photonic Crystals: Semiconductors of Light," Scientific American, December 2001.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 2002	Technical Memorandum

4. TITLE AND SUBTITLE

Physics of Colloids in Space: Flight Hardware Operations on ISS

5. FUNDING NUMBERS

WU–400–32–3A–00

6. AUTHOR(S)

Michael P. Doherty, Arthur E. Bailey, Amy L. Jankovsky, and Tibor Lorik

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–13194

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM—2002-211371
AIAA–2002–0762

11. SUPPLEMENTARY NOTES

Prepared for the 40th Aerospace Sciences Meeting and Exhibit sponsored by the American Institute of Aeronautics and Astronautics, Reno, Nevada, January 14–17, 2002. Michael P. Doherty and Amy L. Jankovsky, NASA Glenn Research Center; Arthur E. Bailey, Scitech Instruments, Inc., North Vancouver, British Columbia, Canada; and Tibor Lorik, ZIN Technologies, Inc., Brook Park, Ohio. Responsible person, Michael P. Doherty, organization code 6728, 216–433–6641.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Categories: 34 and 74 Distribution: Nonstandard

Available electronically at http://gltrs.grc.nasa.gov/GLTRS

This publication is available from the NASA Center for AeroSpace Information, 301–621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Physics of Colloids in Space (PCS) experiment was launched on Space Shuttle STS-100 in April 2001 and integrated into EXpedite the PRocess of Experiments to Space Station Rack 2 on the International Space Station (ISS). This microgravity fluid physics investigation is being conducted in the ISS U.S. Lab 'Destiny' Module over a period of approximately thirteen months during the ISS assembly period from flight 6A through flight 9A. PCS is gathering data on the basic physical properties of simple colloidal suspensions by studying the structures that form. A colloid is a micron or submicron particle, be it solid, liquid, or gas. A colloidal suspension consists of these fine particles suspended in another medium. Common colloidal suspensions include paints, milk, salad dressings, cosmetics, and aerosols. Though these products are routinely produced and used, we still have much to learn about their behavior as well as the underlying properties of colloids in general. The long-term goal of the PCS investigation is to learn how to steer the growth of colloidal structures to create new materials. This experiment is the first part of a two-stage investigation conceived by Professor David Weitz of Harvard University (the Principal Investigator) along with Professor Peter Pusey of the University of Edinburgh (the Co-Investigator). This paper describes the flight hardware, experiment operations, and initial science findings of the first fluid physics payload to be conducted on ISS: The Physics of Colloids in Space.

14. SUBJECT TERMS

Colloids; Microgravity

15. NUMBER OF PAGES

14

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	